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LEIS, a tool for diagnostic and prevision of anthropogenic pressure on natural vegetation: an overview

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ABSTRACT

The desertification process including natural resources degradation is a major obstacle to development in tropical and Mediterranean zones with strong drought constraints, leading to a wide range of possibly irreversible catastrophes: famine, land neglecting and migration. This process comes from a combination of different modes of resource management from different actors at different scales, interacting with strong climatic constraints in arid and semi-arid zones.

In Africa and particularly in the circum-Saharan zone it is urgent to deliver useful information for decision making focused on improving the natural resource management at a local level in order to slow down the desertification process. For that purpose within the ROSELT/OSS program [1], has been developed the LEIS (Local Environmental Information System), an original tool coupling GIS and models to be able to establish a complete diagnostic of natural resource use allowing prediction of future evolutions.

The aim of the LEIS is to model the functioning of an observatory territory at local scale taking into account both biophysical data and socio-economic data together using an integrated spatial approach. Acknowledging the dynamic interactions of these two set of factors the integrated spatial approach is the core of the tool and the conceptual models derive from it. Using minimum kit dataset the modeling of the functioning establishes a diagnostic: spatial description of the uses and resources interactions into spatial references units (SRU) and quantitative estimation of vegetation pressure spatialised on these SRU. The modeling structure allows some prevision to be made when setting a scenario of evolution of parameters. The forecasted diagnostics can be compared for different scenarios while succession of diagnostics in a long term monitoring helps to analyse vegetation pressure evolution and to build realistic scenarii. Before being communicated to local or national authorities, as useful information for a better evaluation of desertification risks, balances maps can then be aggregated according to administrative units or to some biophysics units depending on a specific interest.

Implemented under the same GIS software platform, the LEIS tool couples a geographic database and spatialisation models. In this article we will describe especially the integrated spatial approach which is the core of the tool and the conceptual model deriving from it. Aiming at expressing the prospective potential of the tool, the spatialisation models implemented will be explained.

Keywords: desertification, environmental modeling, landscape, use, natural resource

1 INTRODUCTION

The desertification process including natural resources degradation is a major obstacle to development in tropical and Mediterranean zones with strong drought constraints, leading to a wide range of possibly irreversible catastrophes: famine, land neglecting and migration. This process comes from a combination of different modes of resource management from different actors at different scales, interacting with strong climatic constraints in arid and semi-arid zones.

In Africa and particularly in the circum-Saharan zone it is urgent to deliver useful information for decision making focused on improving the natural resource management at a local level in order to slow down the desertification process.

In this context, the Roselt Programme (Observatory Network for Long-Term Ecological Monitoring), set up by the Sahara and Sahel Observatory (OSS), organises scientific monitoring of the environment in order to characterize the causes and effects of land degradation, and to have a better understanding of the mechanisms which lead to desertification. The network is made up of a number of observatories which operate in a network at regional level in Africa, in the geographical zone of the OSS. This zone comprises three sub regions: North Africa, West Africa and East Africa. ROSELT aims at providing reliable data on land degradation in arid areas and pertinent biophysical and socio-economic indicators of desertification, as well as to assess the state of the environment within the OSS zone. As a network ROSELT aims at harmonising methodologies of data collection and data analysis as well as data or metadata circulation.

For that purpose within the ROSELT/OSS program [1], has been developed the LEIS (Local Environmental Information System), an original tool coupling GIS and models to be able to establish a complete diagnostic of natural resource use allowing prediction of future evolutions. This tool, proposed and developed by the Regional Operator of Roselt (IRD, US Desertification, n°166) is issued from a close working attitude and procedure between methodological research, modelling, computing and information system conceptions, and applications in 9 observatories of 9 circum-Saharan countries, involving numerous researchers from the north and from the south.

The aim of this paper is to give an overview of the tool presented in a poster session of RGLDD 2005, as much in its conceptual aspects as in its implementation.

2 GENERAL PRINCIPLES OF LEIS

The global methodology of the LEIS [4] is to combine biophysical data and socio-economic data together using an integrated spatial approach (fig.1). To be able to distinguish in the landscape the respective parts of factors coming from the above mentioned domains, the spatial approach considers intersecting two planes of distinct information, one linked to uses expression and the other one to natural resources, then defining Spatial References Units (SRU) as a functional description [2]. The renewable natural resources are extracted simultaneously or successively in time for diverse uses (agricultural, pastoral, forest, others) in the majority of arid and semi-arid zone. Therefore, multi-use balances (availability minus extraction of natural vegetation) and anthropogenic pressure indices computations are based and output on this functional mosaic description of the landscape (SRU).

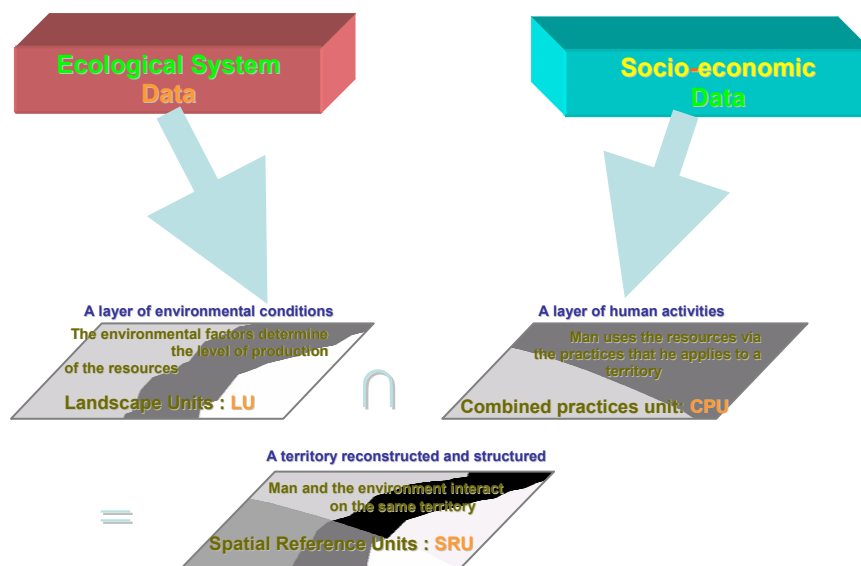


Figure 1. LEIS integrated spatial approach.

The established modeling at a defined period leading to the SRU map and the balances maps resulting on them constitute the diagnostic. The plane of resources expression is built using classical GIS methods on a range of different layers, while the plane of uses comes from spatialisation models of the exploitation practices. These models encompass the originality together with the prediction ability of the tool. From an established Diagnostic, scenarii of evolution of main driving parameters such as population, production (depending on “climate parameters”) allow prospective to be made i.e. leading to new balances maps based possibly on new SRU.

3 MODELING PRINCIPLES OF LEIS

Landscape Units:

The plan of natural resources or plan of environmental conditions distinguishes from a biophysical point of view homogeneous areas called landscape units (LU). The Landscape Units are immediately visually perceptible. From a methodological point of view, the LUs are the result of the interaction of three main categories (fig.2) of factors: physical, biological (Land Cover) and human (Land Use in the sense of international classifications: forests, pasture land, cultivated land, etc.).

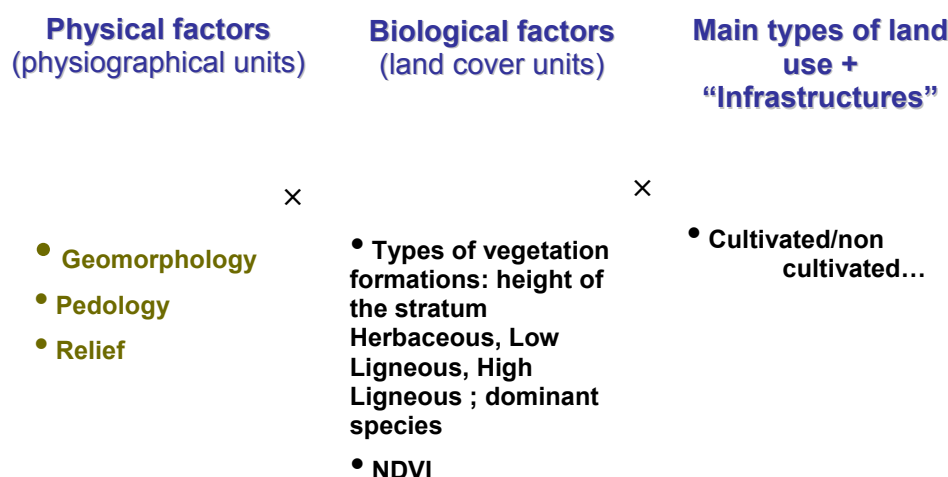


Figure 2. Landscape Units decomposition.

The construction of landscape units calls for classical cartographical methods, combining ground surveys, the use of aerial photos and the processing of satellite images. The limits of landscape units, at a certain level of aggregation or de-aggregation, are common to different biophysical disciplines, at a scale compatible with the changes that Roselt is looking to study. They should have a relative stability in time for given period of diagnostic modeling. The length of this period (usually between 2 and 5 years) is a compromise between the biophysical stability functioning, and the stability of socio-economic functioning. The characteristics of each type of Landscape Unit determine a level of resource production.

Combined practices units

The plan of uses expression or plan of human activities delimits areas, with the same relative stability of LU, which are homogeneous from the point of view of resource exploitation practices.

An exploitation practice is a concrete action of natural resources exploitation led by an exploitation unit according to its exploitation strategy, the biophysical constraints and the objective of production. A class of "combined practices" expresses the simultaneous or successive combination of exploitation practices at the same spatial unit, seasonally or annually

These spatial units are called "Combined Practices Units" (CPU). Contrary to Landscape Units, they are not necessarily visible in the landscape. They are not constructed from processed satellite images and ground surveys, but made from models of spatial distribution practices.

The construction of Combined Practices Units is realised in two main stages:

- the development of the combined practices typology on an observatory territory
- the development of the CPU map via a combined practices spatial distribution model

A particular Combined Practices class issued from the typology associates one or more natural resource exploitation practices, in time and space, with one or more usages. This combination of practices can be applied to different places on the observatory territory on homogeneous spatial units [5]. The occurrences of all the combined practices classes structure the landscape in the Combined Practices Units.

The fundamental principle of the spatial distribution model is as follows: the combined practices are potentially applied to a given location by one or more groups of agents according to:

- the local biophysical characteristics at this location;
- and the expectation that the production of exploitation at this location (average production per exploitation cycle), will contribute to the satisfaction of a type of need

The equation (eq.1) illustrates this principle and is the actual model for agro-pastoral modeling: at pixel px the Combined Practice CP giving the maximum production depending on soil for the minimum effort depending of artificialisation and distance to the CA is spatialised.

$$CP(px) = \arg \max_{cp} \left(\frac{Production(cp, Soil(px))}{Effort(d(px, CA), Artif(cp))} \right) \quad (1)$$

Balances evaluation

The methodology consists in applying an analytical approach by usage with a calculation and spatialisation of the balances on the SRUs for each activity. Availabilities of resources are derived from the LU characteristics while extractions of resources are modelled and spatialised according to the current usage and the structuring usage which built the CPU.

4 MODEL BUILDING STEPS

While establishing a diagnostic at a given period, choices of modelling and data collection is needed at each step of modelling (fig. 3).

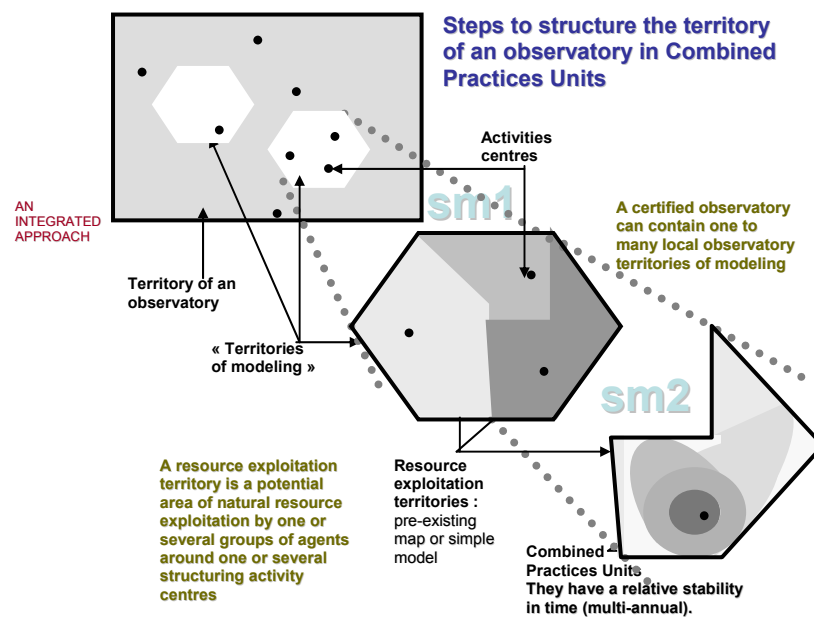


Figure 3. Combined Practices spatialisation models (sm1 and sm2).

(i) Step of spatialisation of the combined practices (CPU) fig3:

- step of delineation of territories of potential exploitation (fig3.sm1)
According to the choice of activity centres (AC e.g. villages, wells, encampments ...) linked to the structuring activity and the choice of the weights (e.g. population, oldness, ...) expressing land competition between CAs a weighed Thiessen algorithm builds a mosaic of polygons of potential exploitation territories around each selected CA;
- typology of combined practices: an agro-socio-economic survey [5] allows to establish a typology of combined practices associated each strategic groups surveyed within the observatory

According to a principle (eq 1.) of maximum production for minimum effort the combined practices are spatialised (fig3.sm2) within each potential territory of exploitation using an algorithm computing the localised production (depending on soil or pastoral quality) and the effort (depending on distance and artificialisation of the combined practice); the extent of exploitation is then limited in order to reach satisfied needs (wished or expected production from the agents)

(ii) **Step of definition of the SRU (fig1):**

The intersection of CPU and LU is done once the Landscape Units are built following some guidance (see Roselt/OSS, SD3) on choosing the different maps expressing the landscape.

(iii) **Step of balances and index computation:**

For each usage a set of CAs together with their specific parameters linked to extraction of resources is chosen. According to a simple model of extraction linked to LU preferences availabilities and extractions are spatialised on the SRU (fig 4).

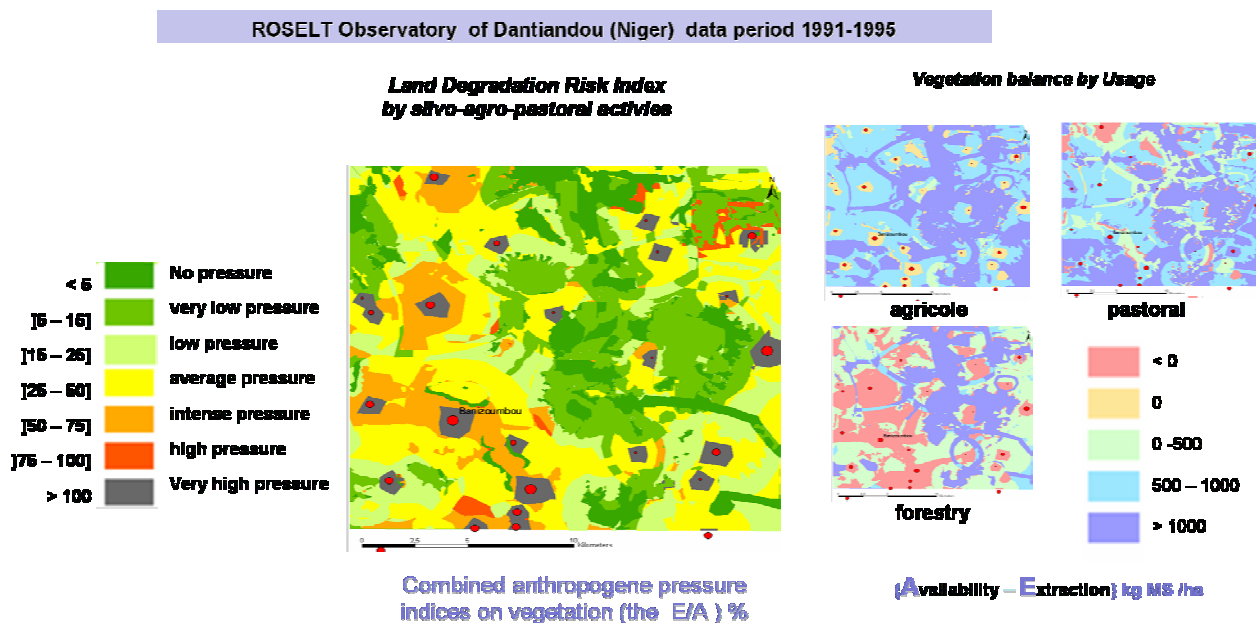


Figure 4. Diagnostic example of vegetation pressure reported on the SRU.

The combined anthropogene pressure indice on vegetation can be considered as a degradation *risk indicator* of the plant resource. It measures the pressure on the environment with regards to the resource (in this case plant resource). It is absolute in the sense that its calculation is made on each SRU without reference to the functioning of the whole observatory. It is therefore comparable from one observatory to another. Whatever the availability of the resources, a quotient greater than 100% potentially indicates, for this unit, a resource extraction that is greater than the availability, which explains the risk. The greater the value of the index, the greater the risk.

(iv) **Step of scenariii:**

Using the driving parameters of the modeling such as population, productions (natural vegetation and or agricultural production) needs it is possible to forecast, according to the chosen scenario of evolutions, the SRU and the balances on this SRU built in the same way as the previous steps (fig 5).

The analysis of tendencies to degradation through diagnoses constitute in oneself a decision making tool. The exploration of these tendencies, through simulations of scenariii, increase the capacity of decision-making aid. Long-term monitoring will allow us to compare the results of simulations with collected data, and thus to validate or readjust the models implemented in the LEIS.

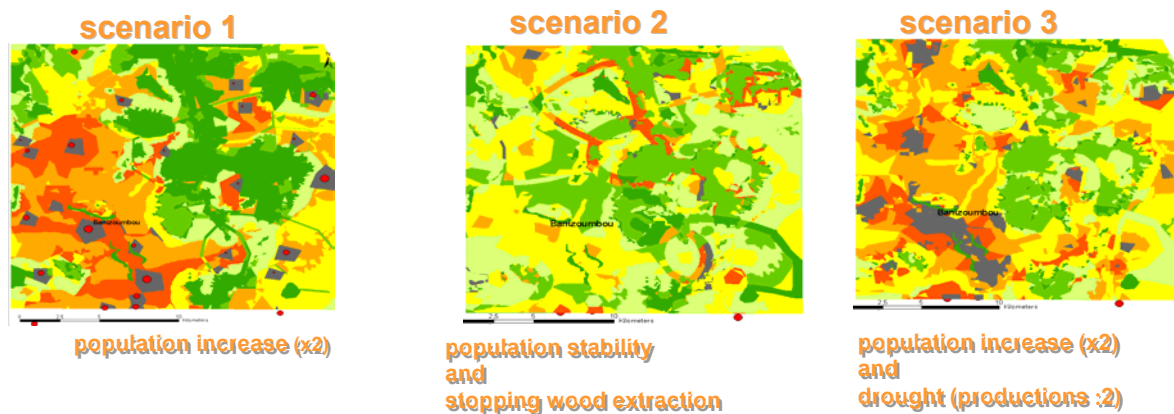


Figure 5. Examples of scenario previsions (Combined extraction index, same legend as fig. 4.).

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5 IMPLEMENTATION OF THE GIS TOOL

Implemented under the same GIS software platform, the LEIS tool couples a geographic database and spatialisation models. The geographic database is organised in relational database management system; its structure was formalised using UML [3] to conceptualise and represent the spatial area-resource-usage interactions at local scale (fig. 6).

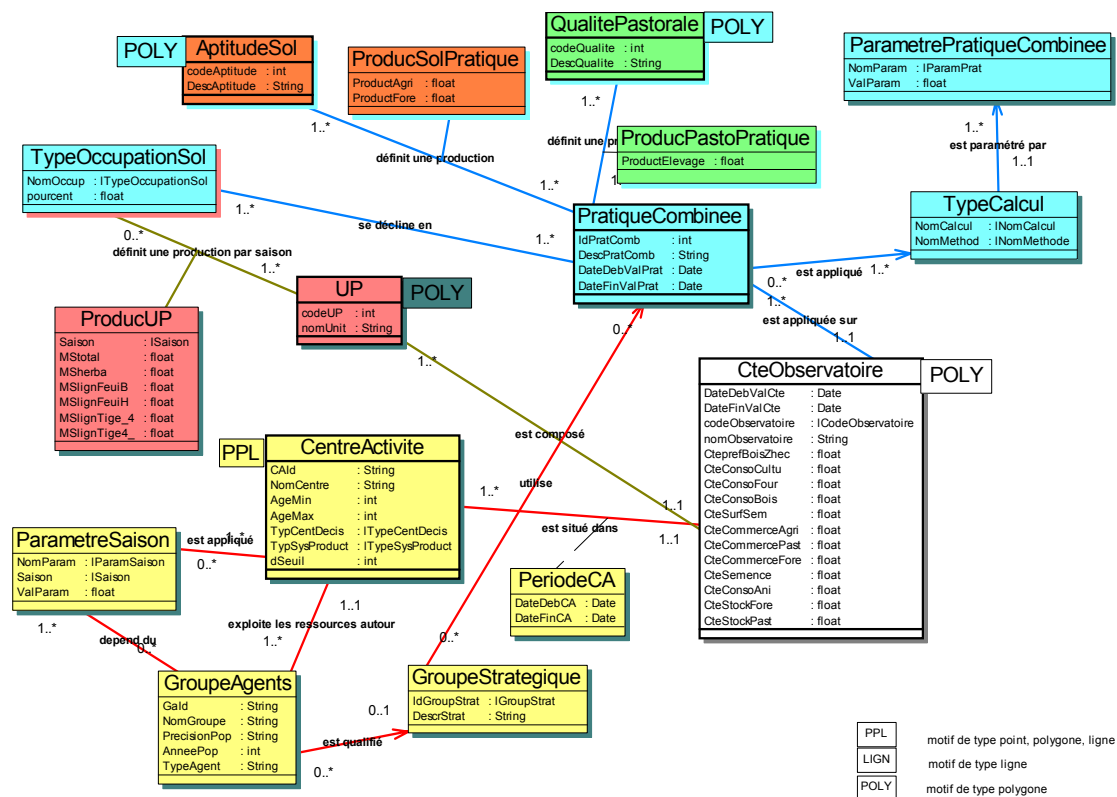


Figure 6. UML diagram of the input data of the LEIS.

Different concepts represented as classes on the diagram of fig 6 are colored according to their different categories but are fully described in the SD3 [4] . The geographic database or GIS database represents here the minimum dataset required to start modelling and grows as the modelling goes from step to step. An extension of ArcGIS has been developed to implement the different steps described above. This extension (fig7) use one GIS database for each observatory but can manage and build more than one modelling at the same time. This allows different tries at different steps in order to initiate validation of the results according to different choices of modelling.

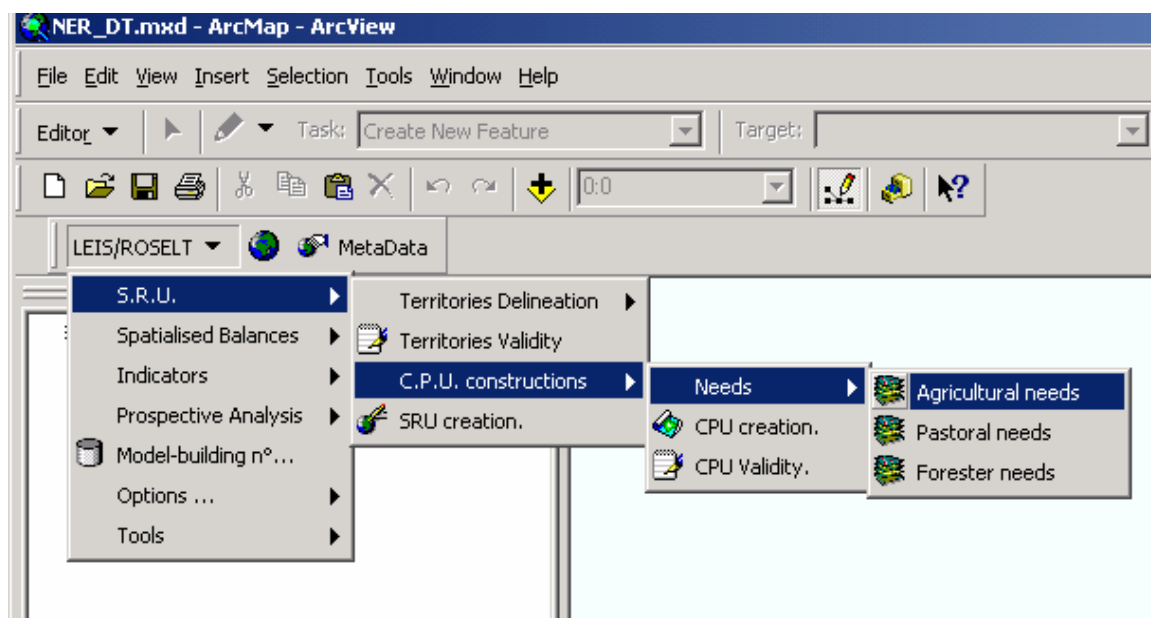


Figure 7. General User Interface of the LEIS tool.

Despite the friendly general user interface LEIS is a tool dedicated to scientists of the domain.

6 PERSPECTIVES AND CONCLUSIONS

Within ROSELT network a full diagnostic prototype of LEIS according to the modelling descriptions here exposed shortly has been done in 4 observatories out of 11 pilot observatories. The results of modelling are actually in validation process. The others observatories are at different stages progressing to establish it. The interest in the tool and the dynamical impact on the other monitoring activities of the network from scientists up to decision makers make the LEIS an important decision tool of the environmental monitoring setting. The integrated approach and methods to establish resource/use spatial balances provide:

- an organisation of data collected from biophysical and socio-economical origins in an integrated schema;
- an activity timetable for the observatories;
- an adaptation of the sampling and data collection for the study of long-term man/environment interactions;
- a harmonisation of the data, of its survey and processing methods from one observatory to another;

All these integrated methodologies contribute to build the national networks of observatories for environmental surveillance in the NAP/CD (National Action Plan to combat desertification) context. The definition of the methodologies to change scales, from the local level to the national level, and reciprocally, are a major current concern of the ROSELT network.

To fully exploit the modelling aspects allowing prospective better scenarii have to be used. First of all realistic climatic scenarii and their impacts on natural vegetation productions as well as crop productions have to be implemented. This is the improvement looked for within the European programme DeSurvey in linking the LEIS model with the PATTERN model [6] which was used in MODULUS a tool similar to LEIS but focused onto policy decision making in the Mediterranean area.

ACKNOWLEDGMENTS

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